

# **Executive Summary**

Extracted from

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**Federal Building and Fire Safety Investigation of the  
World Trade Center Disaster**

## **Active Fire Protection Systems (Draft)**

## EXECUTIVE SUMMARY

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In the event of a fire in a building, the safety of occupants and first responders and the protection of property is accomplished through a combination of passive and active means. A passive fire protection system is one which is an integral part of the building layout and materials of construction, such as partitions to confine the fire, a stairway to assist rapid evacuation, or spray-on fire proofing to increase the fire resistance of a load-bearing steel structure. Active fire protection systems are designed to come into play only when a fire is present and require activation through a combination of sensors or mechanical means. The active fire protection systems in World Trade Center (WTC) 1, 2, and 7 consisted of fire sensors and alarms, notification systems, sprinklers, water supplies, and smoke management systems. Active and passive fire protection systems work together to control the spread of the fire and maintain the integrity of the structure; however, the fire department is always relied upon to fully extinguish the fire and rescue occupants who may be immobilized.

The automatic fire sprinkler systems in WTC 1, 2, and 7 were the first line of defense. Water stored in the building from public sources or pumped from fire apparatus was supplied through dedicated piping to the area of the fire. Also present in the buildings were hoses, preconnected to a water supply through standpipes located in the stairwells and other utility shafts. The standpipes provided hose connections at each floor for The Fire Department of the City of New York (FDNY). In addition, standpipe preconnected hoses were installed for trained occupants to manually suppress fires.

The heart of the fire detection system was the automatic fire alarm and emergency notification system. Occupants in the building depended on this system to detect fires and provide information for emergency evacuation. Capabilities were also designed for the ventilation system to operate in a way to purge smoke produced by fires from the building. Smoke purge was intended to be used for post-fire clean-up but could be used during a fire event at the discretion of the FDNY.

This report includes an examination of the design and installation of the active fire protection systems in WTC 1, 2, and 7 and a description of the normal operation of fully functional systems and their potential effect on controlling the fires on September 11, 2001. The applicable building and fire codes and standards, as well as the history of fires in these buildings, are also documented.

### **E.1      SIGNIFICANT FIRES PRIOR TO SEPTEMBER 11, 2001**

Significant fires in WTC 1, 2, and 7 prior to September 11, 2001, were of interest to the investigation, particularly those that activated multiple sprinklers or where hoses were used to suppress the fires. Because the records of fire events in the buildings maintained by The Port Authority of New York and New Jersey (PANYNJ) were destroyed in the fire and collapse of WTC 1, information available for study was limited to that from FDNY fire and investigation reports.

A major fire occurring in WTC 1 in 1975, prior to the installation of sprinklers, and the bombing of the WTC towers in 1993 were the most significant incidents in the history of these buildings. In addition, 47 other fires were identified that were substantial enough to activate a sprinkler or require hoses to suppress the fire. Sixteen fire incidents exercised multiple sprinklers or multiple standpipe connected

hoses (with or without the activation of at least one sprinkler). Thirty-one fires involved the use of one standpipe hose or one standpipe hose and discharge of one sprinkler. Only three fires were identified to have occurred in WTC 7 prior to 2001. The FDNY fire reports and fire investigation records obtained by the National Institute of Standards and Technology (NIST) indicate that in areas protected by automatic sprinklers, no fire activated more than three sprinklers.

## **E.2 SPRINKLERS, STANDPIPES, AND PRECONNECTED HOSE SYSTEMS**

The evaluation of the sprinklers, standpipes, and preconnected hose systems was performed by subject experts at Hughes Associates, Inc., under contract to NIST. The project documented the design, installation, and operation of the fire suppression systems in WTC 1, 2, and 7; evaluated the consistency of the sprinkler and standpipe systems installations with best engineering practices; described the New York City (NYC) water supply system and evaluated the sprinkler system water supply; and estimated suppression system performance when challenged with design fire scenarios assumed in standard engineering practice as well as with a fire scenario similar to that which occurred on September 11, 2001.

Major features of the fire suppression systems are documented based on a review of the available information. In addition to describing in detail the sprinkler, standpipe, and preconnected hose systems, special fire suppression systems are briefly discussed. System features documented include riser systems, zone arrangements, water tanks, pumps, fire department connections, control valves, and hose rack arrangements. Additionally, documentation of the sprinkler, standpipe, and preconnected hose system installations was examined for consistency with the applicable installation standards and state-of-the-art engineering practices at the time of system installation.

A description of the NYC water supply, including sizes, locations, and directions of water mains surrounding the WTC complex and distribution system within the buildings is provided to adequately evaluate the primary source of water for the automatic sprinkler and hose systems. Adequacy of the sprinkler system water supply was based on a detailed review of the available documentation. Flow capacity and duration of water supplies to the installed sprinkler systems were estimated using industry-accepted software. Hydraulic calculations were performed with variations in primary and secondary water supplies, the number of sprinklers flowing, and floor level elevations. The results from the calculations were used to evaluate the expected sprinkler system performance.

Multiple fire scenarios were analyzed in order to more fully understand the potential impact of the suppression systems to provide the flow of water required to control typical office fires within high-rise buildings. The analysis included single fires on different floors in the towers and in WTC 7 with various combinations of sprinklers activated and with primary and secondary water supplies. Additionally, hydraulic calculations based on simultaneous fires on up to a total of nine floors were performed. Estimates of suppression system performance in WTC 1, 2, and 7 on September 11, 2001, were also made.

The following list summarizes the findings of the suppression and water supply study:

- Except for specific areas that were exempted from required sprinkler coverage, sprinklers were installed throughout WTC 1, 2, and 7 on September 11, 2001.

- According to the documentation examined, the fire suppression systems in WTC 1, 2, and 7 were installed, for the most part, in a manner consistent with state-of-the-art practices in existence at the time of their installation. The installations as documented, with several minor exceptions, would satisfy current best practices.
- Storage tanks, along with direct connections to the NYC water distribution system, supplied water for WTC 1 and WTC 2, and for floors 21 through 47 of WTC 7. Fire suppression systems for floors 1 through 20 in WTC 7 were supplied directly through the NYC water distribution system and an automatic fire pump, with no secondary supply.
- The installation of the supply piping from the storage tanks on the 110th floor in WTC 1 and WTC 2 resulted in restricted flow capacity to several floors. The flow capacity was sufficient to supply the suppression systems, but the installation was not consistent with current engineering best practices.
- The suppression systems in WTC 1, 2, and 7 required manual initiation of the electrical fire pumps in order to provide supplemental water. An automatic supplemental water supply has been required by National Fire Protection Association (NFPA) 14 for some time and represents best practice. Due to extensive damage to the sprinkler and standpipe systems in WTC 1 and WTC 2 on September 11, 2001, it is doubtful that automatic pumps would have made any difference in performance.
- The supply risers for automatic sprinkler systems in WTC 1, 2, and 7 were configured to provide redundant capabilities. However, the sprinkler floor level controls were installed with one connection to the sprinkler water riser. This represented a single point of failure location for the water supply to the sprinklers on that floor.
- The water flow capacities of the sprinkler systems installed in WTC 1, 2, and 7 were designed to provide densities considerably greater than typically provided for high-rise office buildings. Based on hydraulic calculations, it was estimated that the sprinkler systems could have controlled a typical fire at a coverage area up to two to three times the specific design area of 1,500 ft<sup>2</sup>. However, a coverage area of 4,500 ft<sup>2</sup> constitutes less than 15 percent of the area of a single floor.
- The standpipe and preconnected hose systems were consistent with the applicable requirements in the Building Code of New York City (BCNYC). They were not consistent with the flow rates and durations specified by NFPA 13.
- The loading berth and fuel oil pump rooms in WTC 7 were protected by dry-pipe sprinkler systems. The first floor room containing the 6,000 gal fuel oil tank was protected by an Inergen clean agent fire suppression system.
- The fifth floor generator room was not equipped with a sprinkler system, consistent with the BCNYC. No information was found that indicated that the generator/fuel day-tank enclosures elsewhere in WTC 7 were protected by a fire suppression system.

- Primary and backup power were provided in all three buildings, but the absence of remote redundancy of the power lines to emergency fire pumps could have affected the operability of the sprinkler and standpipe systems once power was lost.
- Due to the magnitude of the initial fires and the likely aircraft impact-induced damage sustained to the suppression systems infrastructures in WTC 1 and WTC 2, it is not unexpected that the suppression systems present in these buildings failed to control the fires on September 11, 2001.

### **E.3 FIRE ALARM SYSTEMS**

The evaluation of the fire alarm systems, a review of applicable codes and standards, documentation of the normal operation of fully functional fire alarm systems, and their potential performance in WTC 1, 2, and 7 on September 11, 2001, were performed by subject experts at Rolf Jensen and Associates, Inc., under contract to NIST.

Major features of the fire alarm systems in WTC 1, 2, and 7 are described based on a review of the available documentation. Details on the fire command station, fire alarm system functions, fire alarm system installation criteria, control panel configurations, fire alarm devices, and firefighter telephone system are provided. Additionally, the staff emergency response plan that provided direction for emergency response is outlined. The responsibilities of the fire safety director, deputy fire directors, assistant fire safety coordinator, and floor wardens are described.

For WTC 1 and WTC 2, performance on September 11, 2001, was documented based on brief images of illuminated status lamps on the system's control panels, which were filmed during the event, and through interviews with people who were in the buildings at the time. The performance of the WTC 7 fire alarm system was assessed on the basis of the printout of the fire alarm system's remote monitoring system.

The following is a summary of findings based upon the review of the building designs and analysis of the various fire alarm systems:

- Because the WTC 1 and WTC 2 fire alarm system required manual activation to notify building occupants, the alarm signal was delayed until 12 min after impact in WTC 1.
- The telephone circuits and the notification appliance circuits were not required to have the same performance requirements as the signaling line circuits.
- Attempts were made to use the firefighter telephone systems in WTC 1 and WTC 2 on September 11, 2001; however the system was not functioning.
- Although the fire alarm systems in WTC 1 and WTC 2 used multiple communication path risers, the systems experienced performance degradation, especially in WTC 1 where all fire alarm notification and communication functions appear to have been lost above the floors of impact.

- The fire alarm system installed in WTC 7 sent to the monitoring company only one signal indicating a fire condition in the building on September 11, 2001. This signal did not contain any specific information about the location of the fire within the building.

## **E.4 SMOKE MANAGEMENT**

Subject experts at Hughes Associates, Inc., under contract to NIST, evaluated the design and installation of the smoke management systems in WTC 1, 2, and 7, reviewed applicable codes and standards, and documented the normal operation of the fully functional smoke management systems and their potential effect on smoke conditions in WTC 1 and WTC 2 on September 11, 2001.

The review of building codes and standards determined those that were applicable to WTC 1, 2, and 7. Specifically, the versions of BCNYC that applied and the local laws that were enacted which pertain to smoke management are presented. This review was used as a basis for documenting building designs and evaluating system performance. Descriptions are provided of the basic architecture of each building as it pertains to the establishment of smoke control zones, heating, ventilation and air-conditioning (HVAC) components and layout relevant to smoke management, and sequences of operation of smoke management systems (i.e., activation of fans and positioning of dampers to control airflow during smoke control operations).

Smoke management system performance of WTC 1 and WTC 2 was evaluated based on the understanding of the systems developed during the design reviews. Analysis was performed using industry-accepted software to analyze the interaction between the building and the HVAC systems to determine the extent to which building pressures could be maintained in order to control or prevent the spread of smoke from a zone of fire origin to the rest of the building. The ability of the documented smoke management system to perform under typical design fire scenarios was analyzed along with the ability of the – assumed to be fully functional – system to perform given the damage sustained and the extreme fire/smoke conditions that developed as a result of aircraft impacts on the building.

In order to more fully understand the potential impact of smoke management systems within high-rise buildings, multiple smoke management strategies, design fire scenarios, building configurations and weather conditions were analyzed. In total, a set of 180 simulations were performed, and results were evaluated.

The following are findings from the evaluation of the smoke management systems:

- The smoke management systems in WTC 1 and WTC 2 were not initiated on September 11, 2001.
- Had the smoke purge sequence been initiated in WTC 1 or WTC 2, it is unlikely the system would have functioned as designed, due to damage caused by aircraft impacts.
- WTC 1 and WTC 2 were not required by the 1968 BCNYC, as amended by Local Law 5 and Local Law 86, to have active smoke and heat venting and/or stair pressurization because they contained automatic sprinklers throughout.

- Even if fully operational, none of the potential smoke management systems evaluated would have prevented smoke spread given the damage caused by aircraft impact.
- During the events occurring on September 11, 2001, stair pressurization would have been ineffective in improving conditions for occupants trying to exit the building.
- Installation of combination fire/smoke dampers in HVAC ductwork, which was not required in WTC 1 or WTC 2, may have acted to slow the development of hazardous conditions on the uppermost floors of the building, but would likely not have had a significant effect on the ability of occupants to egress the building due to the impassibility of the exit stairways.